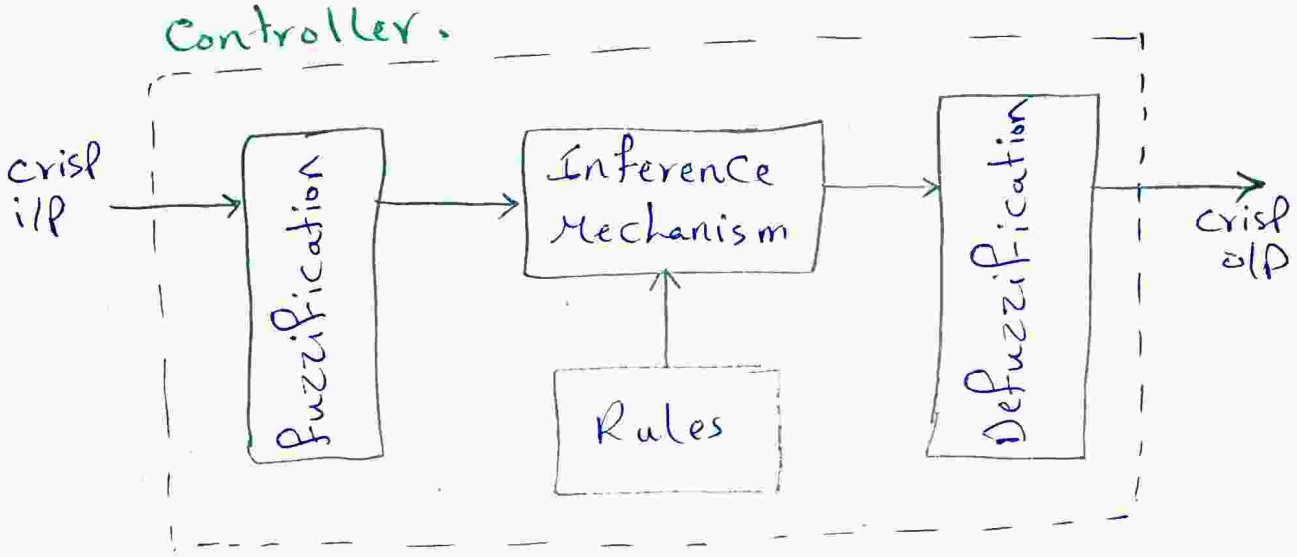
Fuzzy: Final 2016

Q-1

a) Explain the main structure of fuzzy controller.



1) Fuzzification
↳ Convert crisp values of fuzzy controller input into fuzzy input sets.

2) Rules & inference mechanism

Rules: set of If-then statements, that governs the performance of controller.

Inference mechanism: emulates the expert's decision making in interpreting & apply knowledge about best to control plant.

3) Defuzzification:
↳ Inverse process of fuzzification (convert fuzzy quantity into crisp value)

Q1.b) what are the main differences between Mamdani and TSK fuzzy Controller:

1) The difference in the rules

a. In Mamdani : rules obtained from an experienced human operator.

for ex

R1: if X_1 is A_1 and X_2 is B_1 then y is C_1

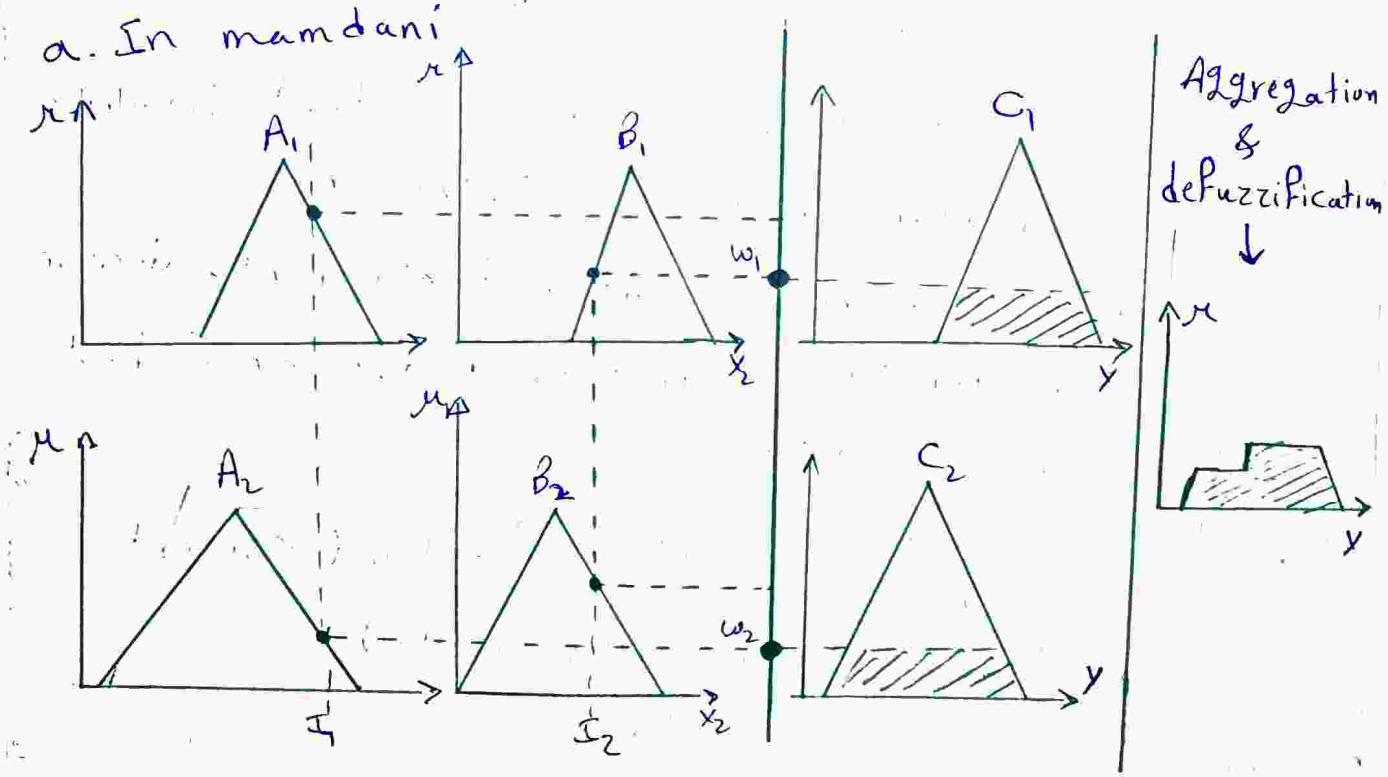
b. In TSK (rules) linear function which is combination of input variables + Constant term

EX

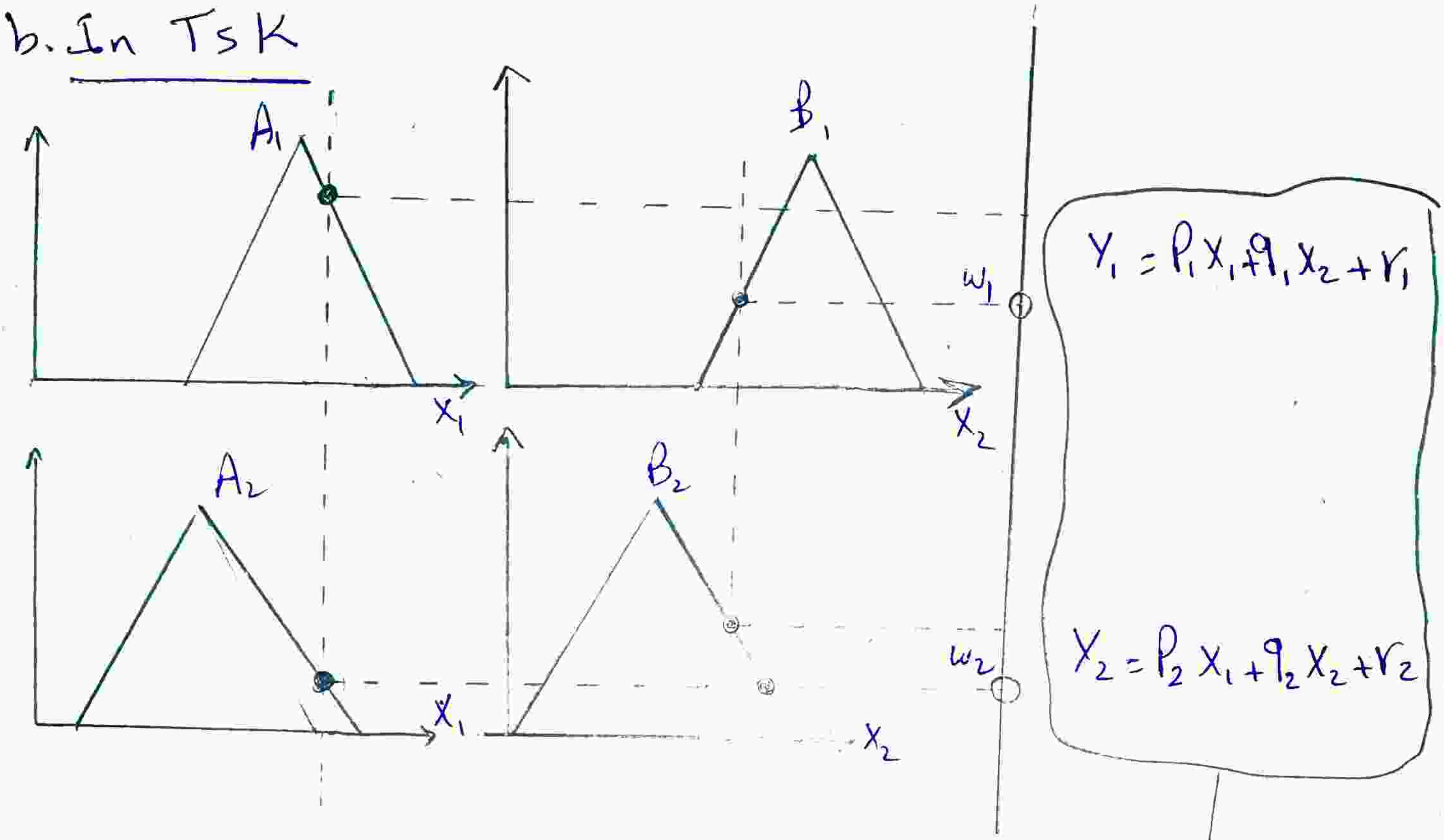
R1: if X_1 is A_1 & X_2 is B_1 then $Y_1 = P_1 X_1 + q_1 X_2 + r_1$

2) The difference in way of apply defuzzification

a. In mamdani



b. In TSK



weighted average

$$Y^{crisp} = \frac{w_1 Y_1 + w_2 Y_2}{w_1 + w_2}$$

← ممكن لو عطلت معاك ف جزء ال defuzzification

تقول إن الغرض هو كده:

1) Way of defuzzification

a. In Mamdani

* center of gravity. * weighted average

* Mean-max membership.

b. In TSK

↳ weighted average.

Q1. c) Explain the following.

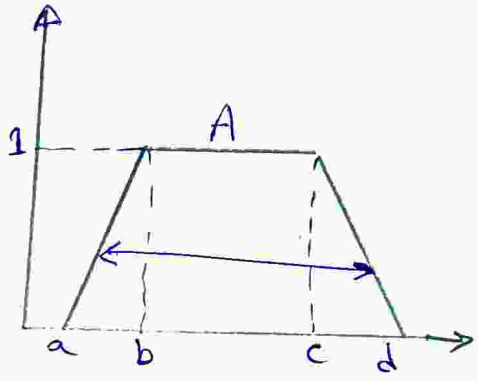
support - core - single ton

1. support

↳ elements of fuzzy sets where its MF degree $\neq 0$

ex

support (H) = $]a, d[$



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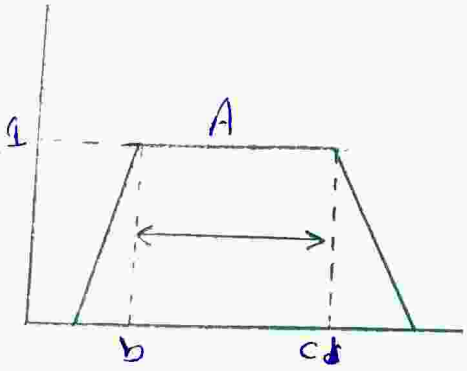
2. Core

↳ elements of fuzzy set where its MF degree is equal to 1

Core (H) = $[b, c]$



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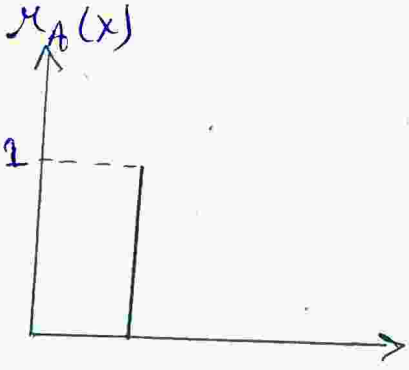
3. single ton

↳ when no. of elements of fuzzy set is equal to 1 with $\mu = 1$, it is called single ton.



Q1. d) What are the advantages of using Fuzzy Controllers?

1) Cheap in cost
2) Customizable
3) easy to design and implement.
4) more robustness.

لم متأكد مطلوب نشرحهم ولا لأ بس الشرح موجود في

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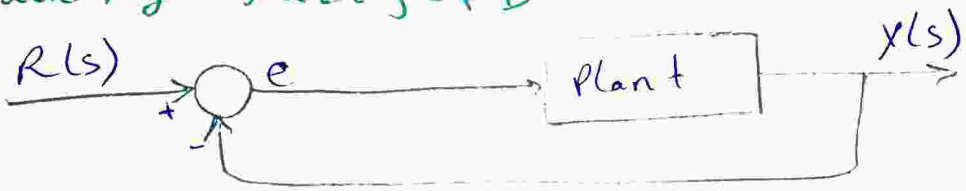
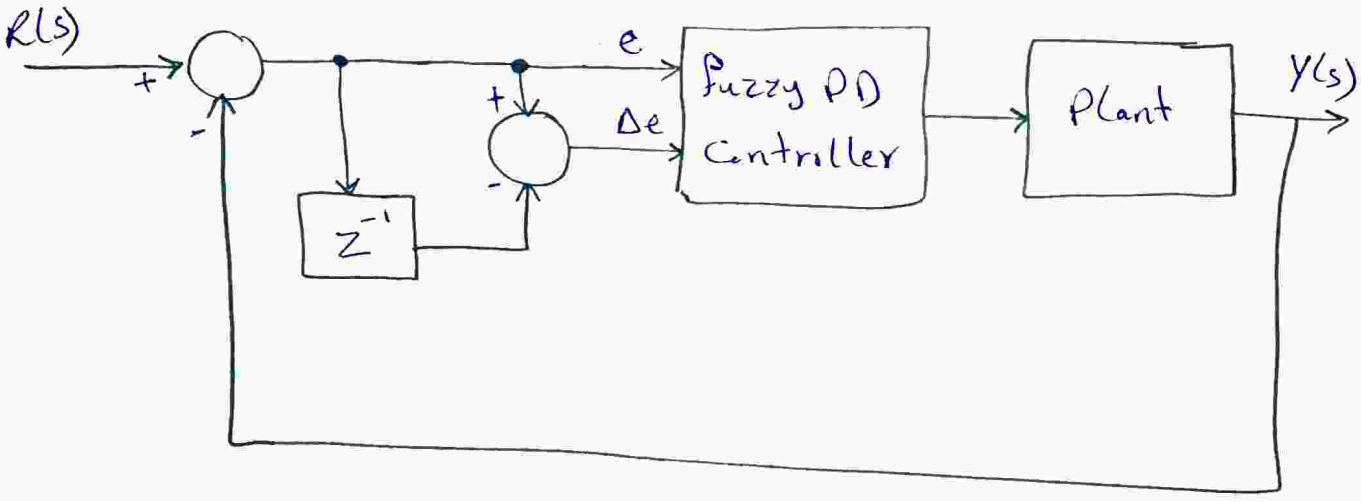
Q1. e) redraw the following system after adding Fuzzy-PD Controller





Q2 using the error signal (e) and change of error (Δe) design Fuzzy-PD controller with following specs:

a) no. of MFs for the inputs (e and Δe) is 5.

b) " " " " = output (u) is 7

c) use (NH, NS, Z, PS, PM) as labels of MFs for inputs (e & Δe)

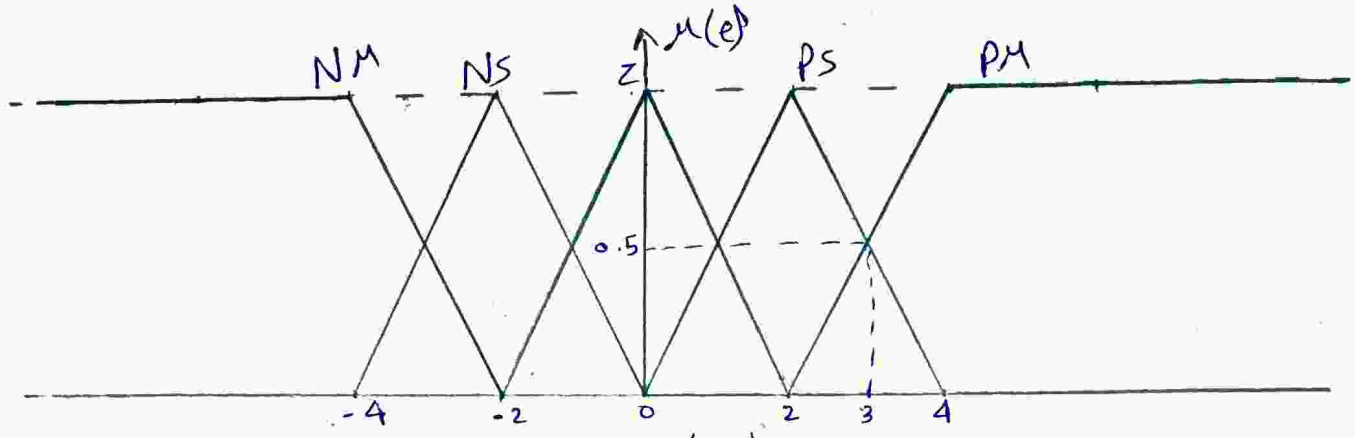
d) " (NL, NM, NS, Z, PS, PM, PL) as labels of MFs for output (u)

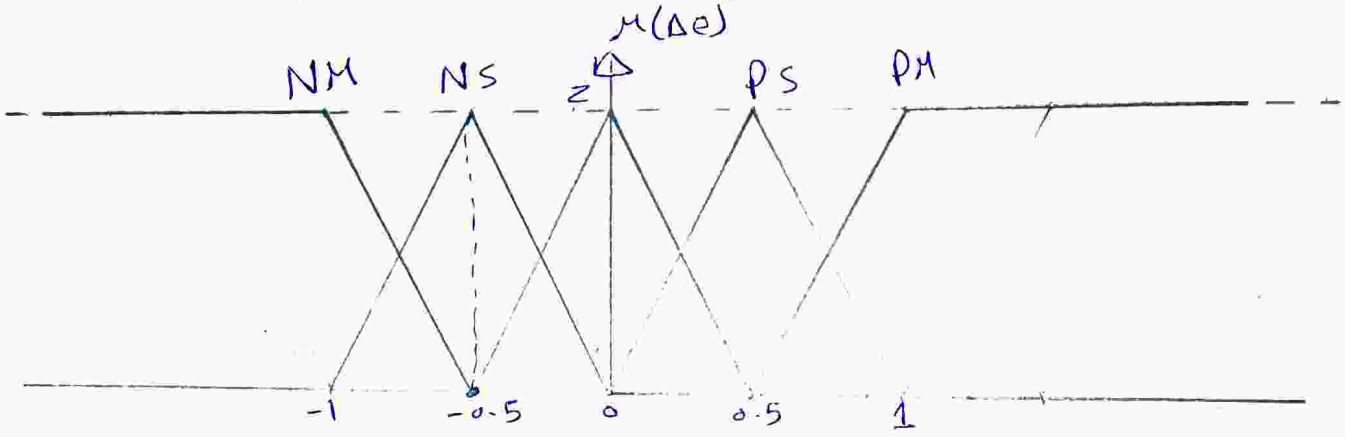
e) the universe of discourse:

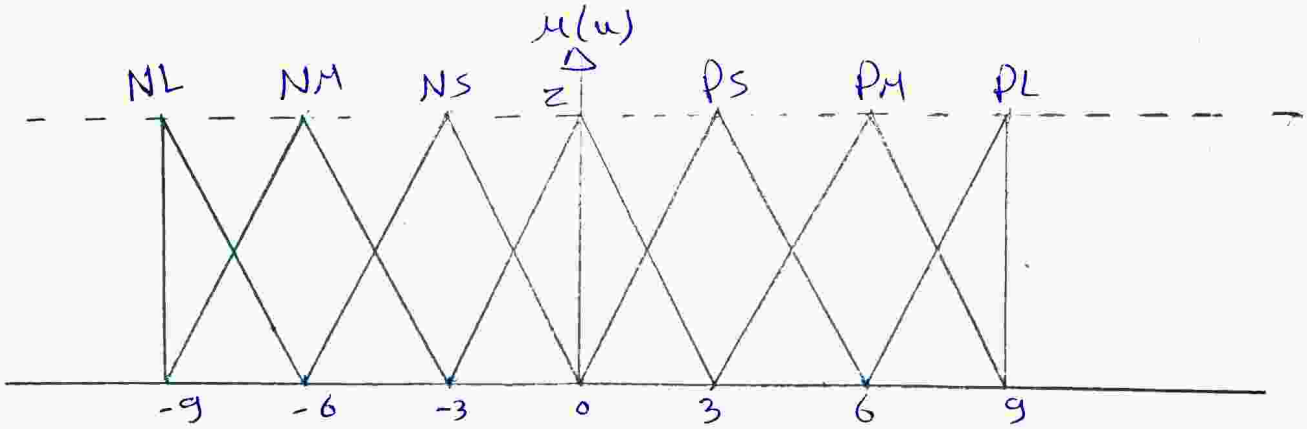
* e → from -4 to 4
* Δe → from -1 to 1
* u → from -9 to 9

1) Draw MFs for input and output
2) write the suitable rules.
3) Find the controller crisp output (u^{crisp}) at $e = 3$ and $\Delta e = -0.5$

Solution starts from next page.







Δe \ e	NM	NS	Z	PS	PM
NM	PL	PL	PM	PS	Z
NS	PL	PM	PS	Z	NS
Z	PM	PS	Z	NS	NM
PS	PS	Z	NS	NM	NL
PM	Z	NS	NM	NL	NL

table of rules

$e = 3$ & $\Delta e = -0.5$

1) Fuzzification

$e = 3$
- → PS with $\mu_{PS}(e) = 0.5$
- → PM with $\mu_{PM}(e) = 0.5$

$\Delta e = -0.5$
- → NS with $\mu_{NS}(\Delta e) = +1$

2) Fired rules

R1: if e is $\overset{0.5}{PS}$ & Δe is $\overset{-1}{NS}$ then u is Z

R2: if e is $\overset{0.5}{PM}$ & Δe is $\overset{-1}{NS}$ then u is NS

3) strength of fired rules

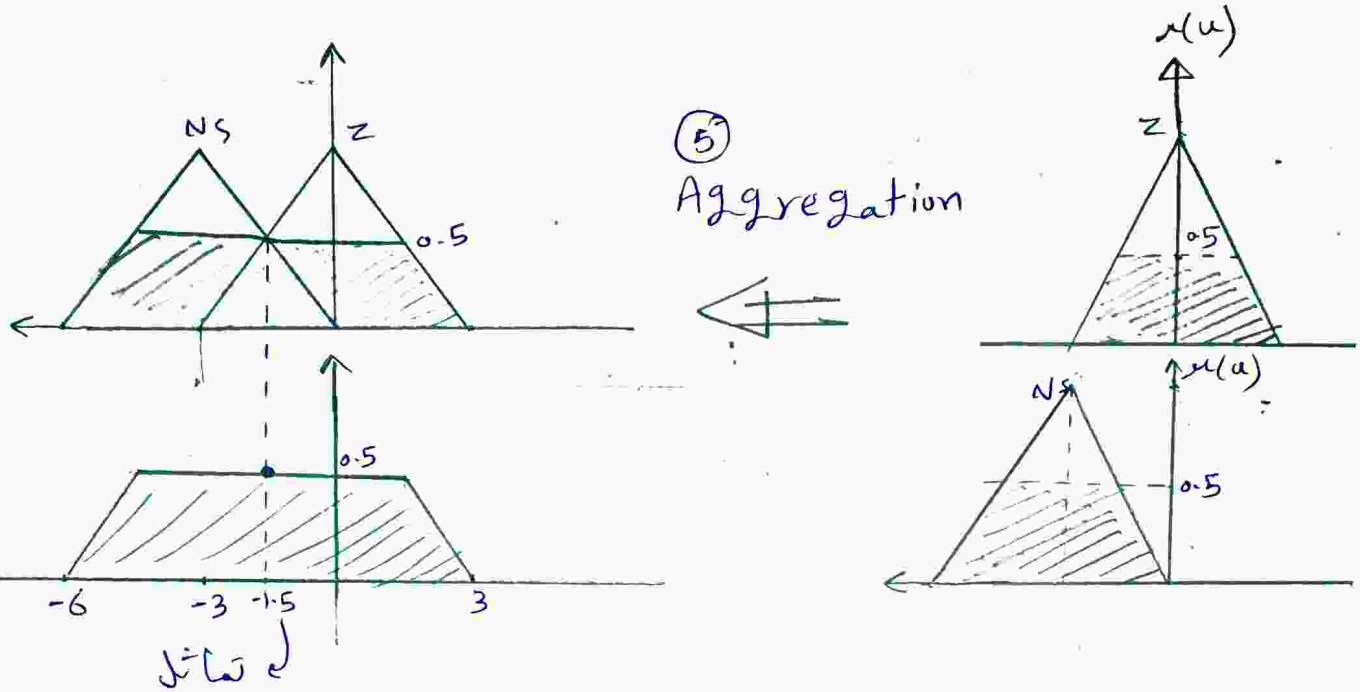
$$\mu_{P_1} = \min\{\mu_{PS}(e=3), \mu_{NS}(\Delta e = -0.5)\} = \min\{0.5, 1\} = 0.5$$

$$\mu_{P_2} = \min\{\mu_{PM}(e=3), \mu_{NS}(\Delta e = -0.5)\} = \min\{0.5, +1\} = 0.5$$

4) Forms of o/p fuzzy sets:-

$$\mu_Z(u) = \min\{\mu_{P_1}, \mu_Z(u)\} = \min\{0.5, \mu_Z(u)\}$$

$$\mu_{NS}(u) = \min\{\mu_{P_2}, \mu_{NS}(u)\} = \min\{0.5, \mu_{NS}(u)\}$$



(5) Aggregation

Aggregation

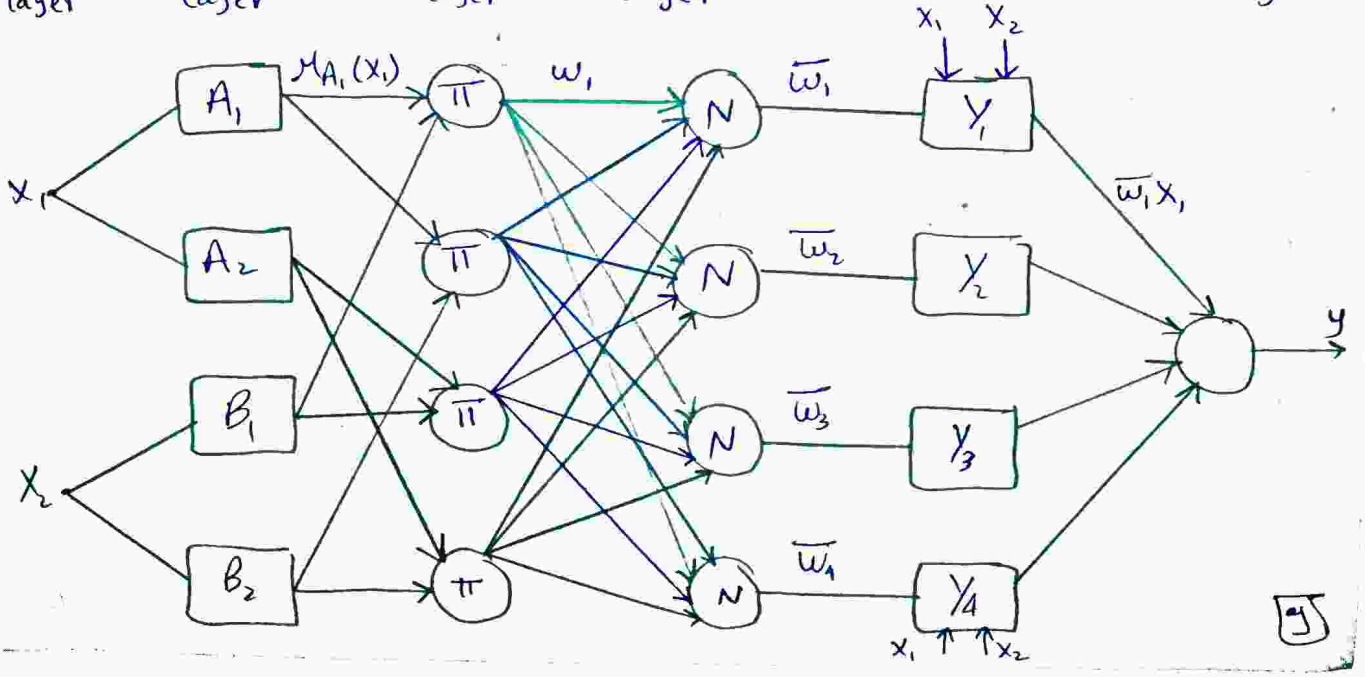
6) defuzzification

$u^{crisp} = -1.5$

Q3 : a

The ANFIS structure is a multi-layered neural network, Explain these layers.

input layer | fuzzification layer | Rule layer | Normalization layer | defuzzification | sum layer



ANFIS Layers

1) Layer 0 : input layer
↳ as inputs are applied to system.

2) fuzzification layer : Layer 1
↳ apply inputs MFs & produce a degree of membership (μ)

3) Layer 2 : Rule layer
↳ Its output represents fire strength of rules.
↳ executes fuzzy of antecedent (if part)

4) Layer 3 : normalization layer:
↳ o/p is ratio of firing strength of ith rules to sum of all firing strength rule.

$$\bar{w}_i = \frac{w_i}{w_1 + w_2 + w_3 + w_4}, \quad i = 1, 2, 3, 4$$

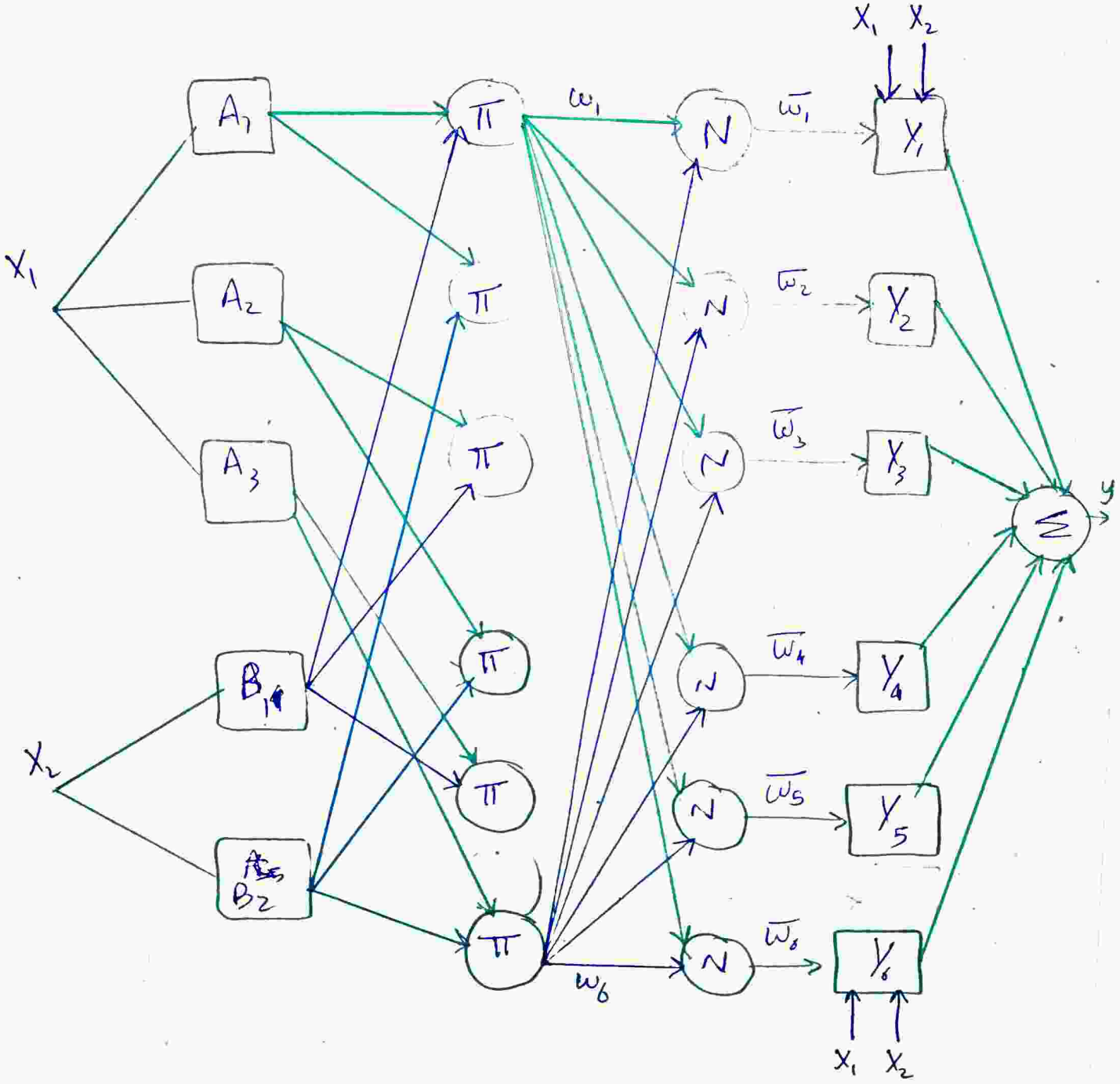
5) Layer 4 : defuzzification layer (then part)
↳ executes the consequent part of fuzzy rules.
↳ its o/p is product of normalized fired strength rule & its corresponding linear function in consequent part.

6) Layer 5 : sum Layer
↳ computes total crisp output of fuzzy system

$$y^{crisp} = \frac{w_1 Y_1 + w_2 Y_2 + w_3 Y_3 + w_4 Y_4}{w_1 + w_2 + w_3 + w_4} = \bar{w}_1 Y_1 + \bar{w}_2 Y_2 + \bar{w}_3 Y_3 + \bar{w}_4 Y_4$$

Q_3 : b)

Draw the ANFIS structure for two input (X_1, X_2) when three MFs (A_1, A_2, A_3) are used for input X_1 and two MFs (B_1, B_2) are used for X_2



Q_3.c) what are the Parameters to be optimized in ANFIS and what are the methods that can be used to optimize these Parameters?

sol

1. Parameters to be be optimized:
   - Premise Part (if-Part)
   - Consequent Part (then-Part)

2. Methods used optimize these Parameters:

   a. derivative-based:
      - backPropagation (BP)
      - least squares estimate (LSE)
      - Hybrid learning (HL)

   b. derivative-free:
      - genetic algorithm (GA)
      - Particle swarm optimization (PSO)
      - differential evolution (DE)
      - shuffeled frog leaping Algorithm (SFLA)
      - artificial bee colony algorithm (ABC)

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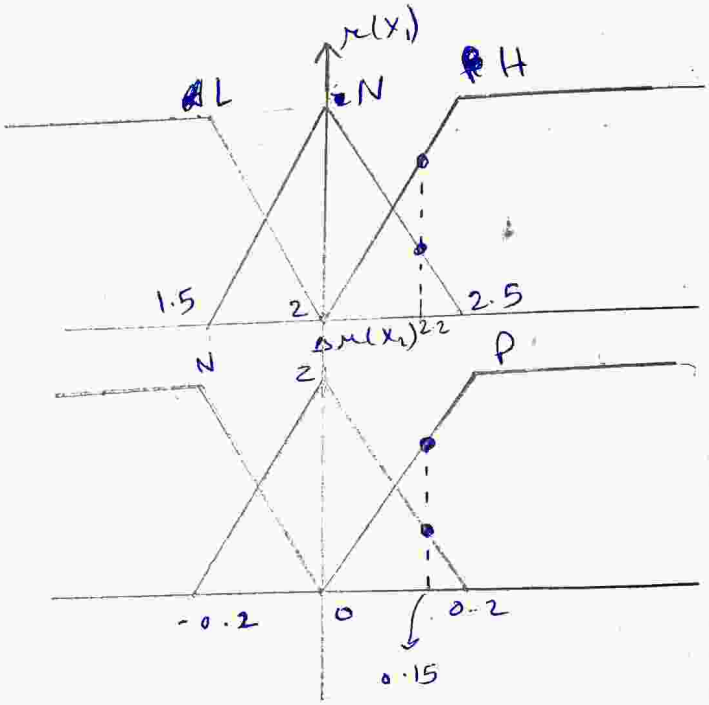
لكنه يفضل تكتبهم طبعاً

$Q_3.d$) A TSK fuzzy controller is designed for a level control process, with two ~~type~~ inputs X_1 (represent the level), X_2 (change in level). The output of the controller u (represent the value position).

The MFs for X_1, X_2



rules of controller:

X_1 \ X_2	N	Z	P
L	Y_1	Y_1	Y_1
→ N	Y_2	Y_2	Y_3
→ H	Y_4	Y_4	Y_4

where: $Y_1 = 4X_1 - 0.25X_2 + 0.05$

$Y_2 = X_1 - 0.1\,X_2$

$Y_3 = 0.5X_1 - 0.1\,X_2$

$Y_4 = 0.2\,X_1 - X_2$

Find the controller crisp output (u^{crisp})

when $X_1 = 2.2$ and $X_2 = 0.15$

1) fuzzification

- $X_1 = 2.2$
  - → H with $\mu_H(X_1) = 0.4$
  - → N with $\mu_N(X_1) = 0.6$

$X_2 = 0.15$
- → P with $\mu_P(X_2) = 0.75$
- → Z with $\mu_Z(X_2) = 0.25$

2) Fired rules

R_1: if X_1 is H & X_2 is P then $Y_4 = 0.2X_1 - X_2$

R_2: if X_1 is H & X_2 is Z then $Y_4 = 0.2X_1 - X_2$

R_3: if X_1 is N & X_2 is P then $Y_3 = 0.5X_1 - 0.1X_2$

R_4: if X_1 is N & X_2 is Z then $Y_2 = X_1 - 0.1X_2$

for $X_1 = 2.2$, $X_2 = 0.15$

$Y_4 = 0.29$

$Y_3 = 1.085$

$Y_2 = 2.185$

معادلة الخط X_1 إلى H

$$\frac{\mu - 0}{X_1 - 2} = \frac{1-0}{2.5-2} = \frac{1}{0.5}$$

$0.5\mu = X_1 - 2 \quad (X_1 = 2.2)$

$\mu = \frac{0.2}{0.5} = 0.4$

معادلة الخط X_1 إلى N

$$\frac{\mu - 1}{X_1 - 2} = \frac{0-1}{2.5-2}$$

$0.5(\mu - 1) = 2 - X_1$

$\mu = 0.6$

معادلة الخط X_2 إلى P

$$\frac{\mu - 0}{X_2 - 0} = \frac{1-0}{0.2-0}$$

$0.2\mu = X_2 = 0.15$

$\mu = 0.75$

معادلة الخط X_2 إلى Z

$$\frac{\mu - 1}{X_2 - 0} = \frac{0-1}{0.2-0}$$

$0.2(\mu - 1) = -X_2$

$\mu = 0.25$

المعادلات سأجل التوضيح فقط

* The Fired rules

R_1: if X_1 is H & X_2 is P then $Y_4 = 0.29$

R_2: if X_1 is H & X_2 is Z then $Y_4 = 0.29$

R_3: if X_1 is N & X_2 is P then $Y_3 = 1.085$

R_4: if X_1 is N & X_2 is Z then $Y_2 = 2.185$

3) strength of Fired rules

$R1: \mu_{P_1} = \min\{\mu_H(X_1), \mu_P(X_2)\} = \min\{0.4, 0.75\} = 0.4$

$R2: \mu_{P_2} = \min\{\mu_H(X_1), \mu_Z(X_2)\} = \min\{0.4, 0.25\} = 0.25$

$R3: \mu_{P_3} = \min\{\mu_N(X_1), \mu_P(X_2)\} = \min\{0.6, 0.75\} = 0.6$

$R4: \mu_{P_4} = \min\{\mu_N(X_1), \mu_Z(X_2)\} = \min\{0.6, 0.25\} = 0.25$

4) Aggregation and defuzzification:

R_1: $Y_4 = 0.29$ with $w_1 = 0.4$

R_2: $Y_4 = 0.29$ with $w_2 = 0.25$

R_3: $Y_3 = 1.085$ with $w_3 = 0.6$

R_4: $Y_2 = 2.185$ with $w_4 = 0.25$

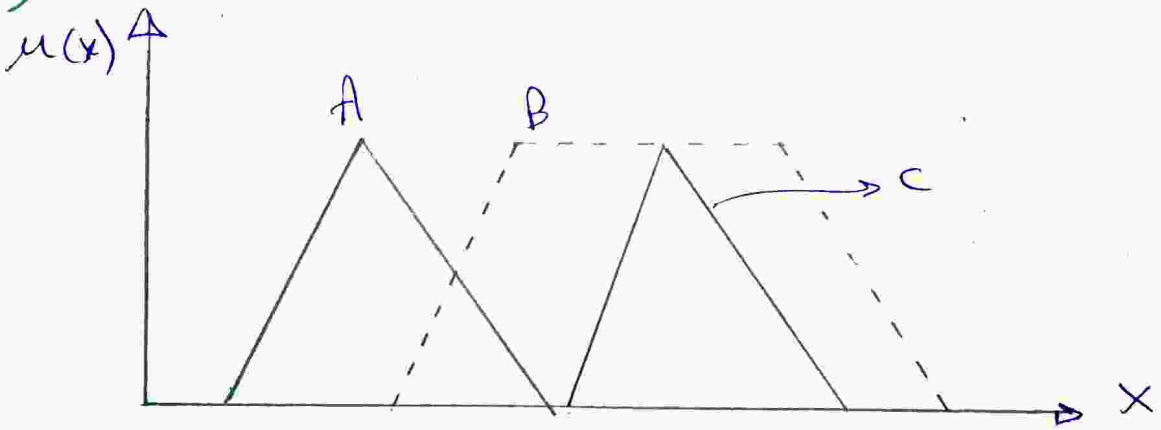
using weighted average method

$$y^{crisp} = \frac{w_1 y_4 + w_2 y_4 + w_3 y_3 + w_4 y_2}{w_1 + w_2 + w_3 + w_4}$$

$$= \frac{0.4 * 0.29 + 0.25 * 0.29 + 0.6 * 1.085 + 0.25 * 2.185}{0.4 + 0.25 + 0.6 + 0.25}$$

$$y^{crisp} = 0.92$$

Q4.a) For the following



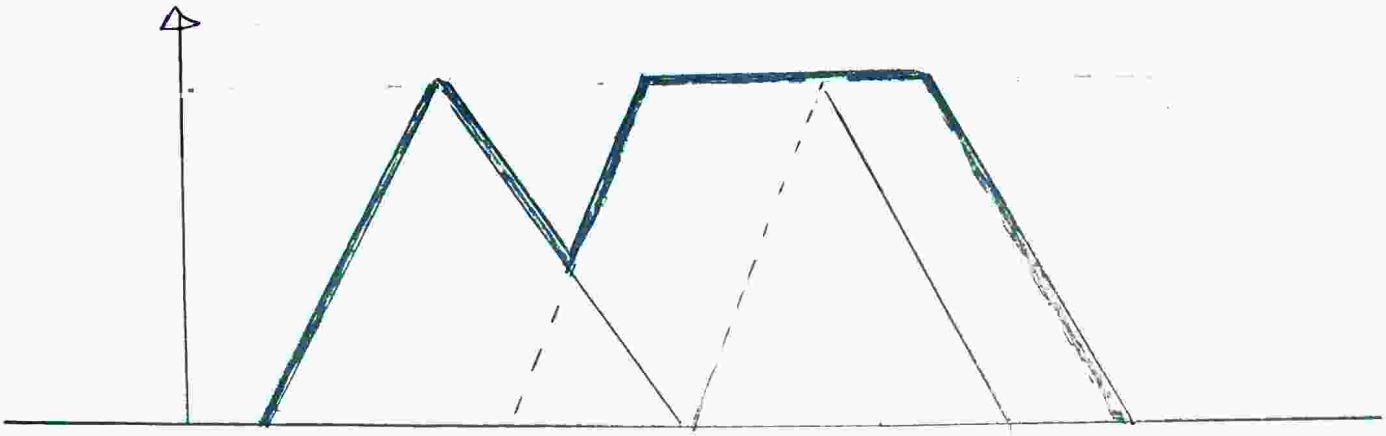
Find $A \cup B \cup C$

Find $A \cap B \cap C$

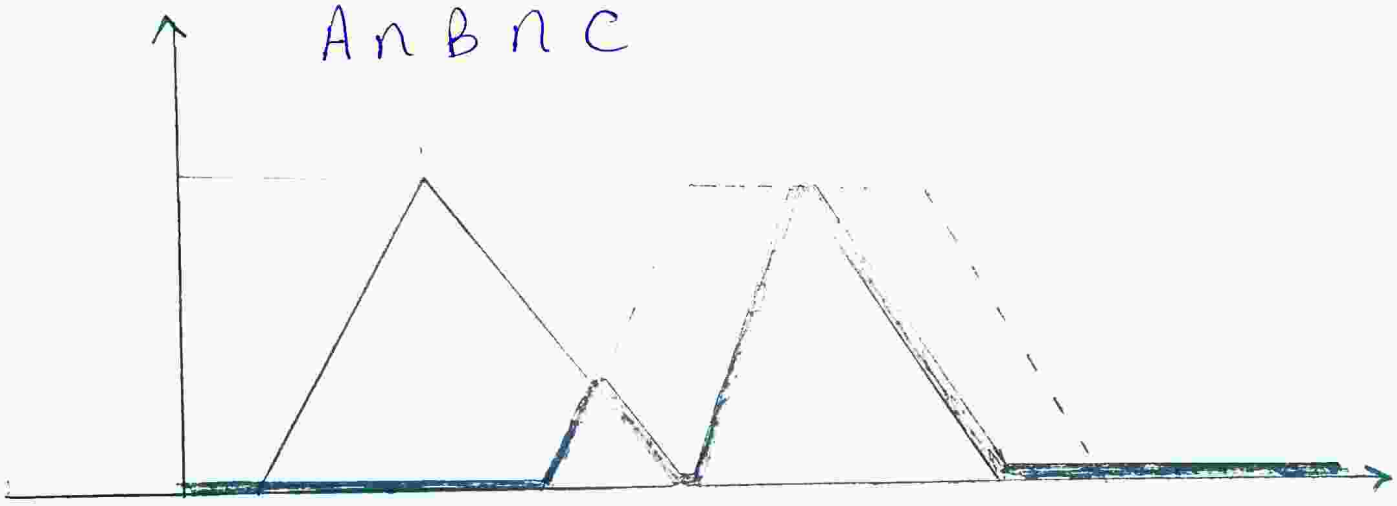
Find $\bar{B}$

$A \cup B \cup C$

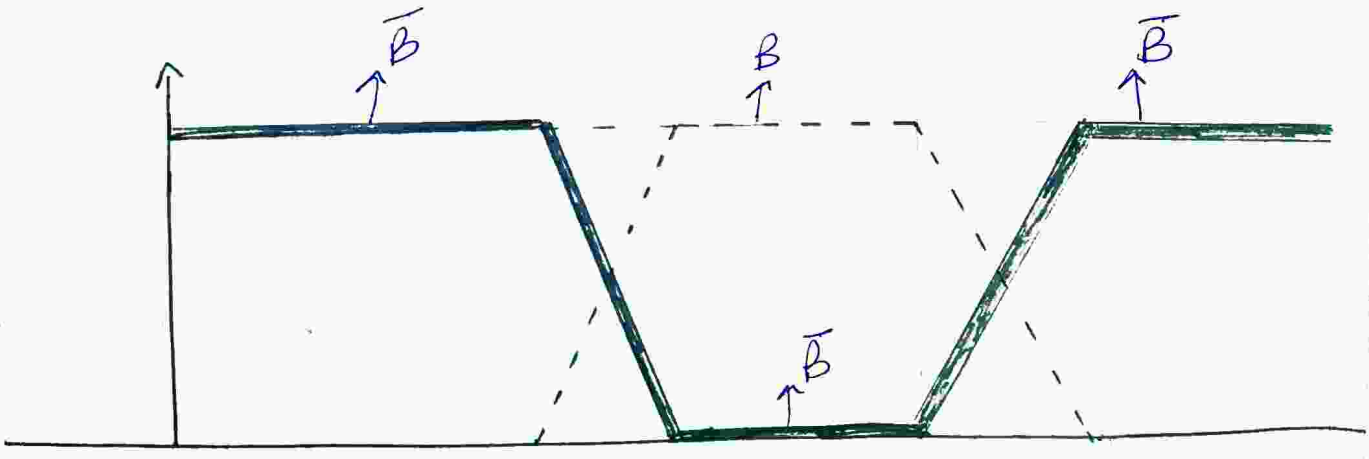
الخط الثقيل هو الإتحاد



$A \cap B \cap C$



$\overline{B}$



Q4. b) write briefly about an application that used an application that uses fuzzy control field & explain the inputs and outputs that used in this app.

لم يفضل كل طالب يكتب الـ (Presentation)
اللى قدمها أ...

هو عايز الـ i/p ، o/p ،
جدول الـ (rules) لو أمكن.
وشرح الـ system